Shaping the Information Supply Chain for M2M Systems

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Abstract: Machine2machine communication is one of the major technology trends for the future internet and for information technology in general. It deals with the communication between machines via internet technology. Such intelligent technical systems are able to coordinate their work or to ask for maintenance automatically. The inherent computing power and communication capability of M2M systems opens new dimensions for the application of technology. Usually, the computing power is integrated into a technical system by adding a specific M2M device, e.g. a small computing and communication node. In future, the deep integration with the technical system is intended. This leads towards cyber physical systems (CPS). CPS connect the material physical world with the cyber space. CPS are expected to be an enabling technology for trends like smart grids, ambient assisted living (AAL), e-mobility and future production systems (the fourth phase of the industrial revolution – industry 4.0). M2M systems are not just monolithic and independent technical systems. They are deeply embedded into the application. The integration with other IT systems (e.g. ERP and PLM systems) and business processes form a so called digital ecosystem. This business information ecosystem is driven by an application specific information supply chain. Designing, maintaining and managing these complex information supply chains is a major trend for IT project management and IT systems engineering. This contribution structures the characteristics of such information supply chains and names the challenges that need to be addressed by IT project management. It is intended to set a starting point for the development of the respective processes, methodologies and tools by formulating research questions for further research in the project management domain.

1. Introduction

The evolution of information technology is one of the main trends of the past decades. It started from a few computers used by several expert users (mainframes), evolved over the personal computer (one fixed computing terminal used by one user) towards today's mobile devices (laptop computers, smart phones, tablets). Due to the ever falling cost of computing power, the trend is expected to continue towards ubiquitious or pervasive computing where computing power is installed everywhere and only recognized by people indirectly. This trend is accompanied by the evolution of the internet which is the main technology for communication between computing devices and therefore between computer users. Since the introduction of IPv6 (the most recent version of the internet protocol) the internet is technically able to connect very high numbers of computing devices (~3.4×10^{34}).

Small communicating computing devices are the basis of some major technical innovation areas such as smart grids (intelligent energy networks), e-mobility (e.g. vehicle2grid communication, car2car communication), ambient assistant living (AAL, enabling homes to support their inhabitants by adding sensors and smart devices) and intelligent logistics and supply chains (e.g.

by using RFID – Radio Frequency Identification). These developments integrate computing power (and maybe some kind of intelligence) and communication capabilities into technical systems – into things. Therefore, the extension of the internet towards connecting things led to the term "Internet of Things – IoT" [3,5,6,8,17]. First, around 2000 the idea was limited to tagging things with an RFID-tag and making them traceable, e.g. in logistics, but soon (around 2005) the idea was extended towards intelligent technical systems and towards being the major driving force for the development of the future internet [3].

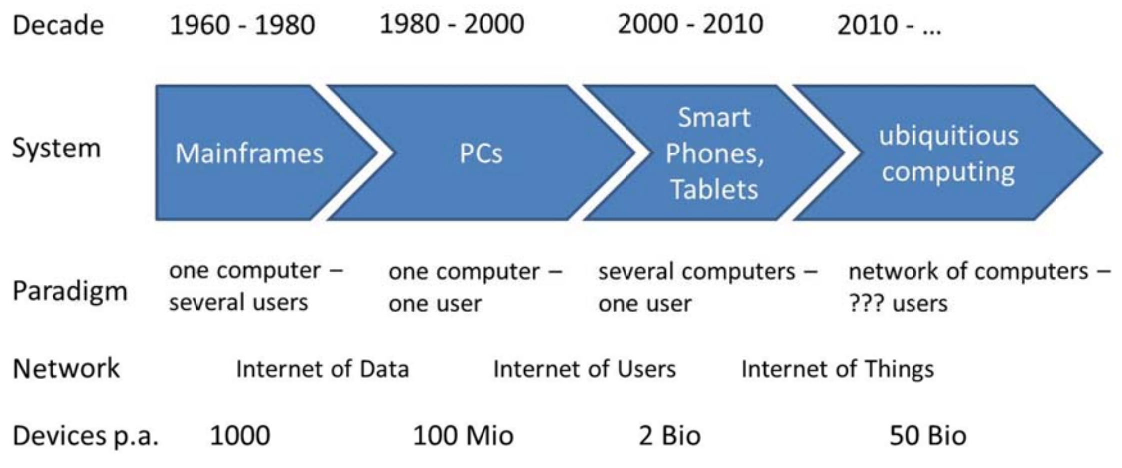

Fig. 1: History and Development of the Computing Domain

The deep integration of computing and communication devices and of advanced IT into technical systems leads towards Cyber Physical Systems (CPS) [1]. Computer science concepts like self-organization and self-optimization can be integrated into technical systems creating so-called intelligent technical systems. The combination with services in the virtual domain (e.g. cloud computing) forming a vertical integration and the provision of interaction technologies for the (human) users open the door towards new and innovative products and systems. A specific part of the Cyber Physical Systems is the communication and collaboration between the computing devices and hence between the "things". This part is called the Machine2Machine (M2M) communication and describes mainly standards, platforms, protocols and methodologies to support this communication [7,13]. Due to the expectation of a very high number (billions, trillions) of communicating devices the market size and the impact for the industry is tremendous. Developing, building, maintaining and operating such M2M systems is therefore one of the major trends for IT project management in future. Especially in Germany, the emergence of Cyber Physical Production System (CPPS) is positioned as the driver for the fourth phase of the industrial revolution (Industry 4.0 [2]) leading towards the production of highly individual products in contrast to today's mass production.

The deep integration of computing and communication devices in Cyber Physical System (or the Internet of Things) creates important aspects apart from technical considerations. CPS have an impact on economic or socio-economic processes and systems. They are tightly connected to both the "real world" and the "cyber space". A CPS cannot be designed or applied without considering the environment it is placed into. Understanding the holistic view of the application of IT systems, the term "Digital Ecosystem" emerged [5,10,12]. Especially the economic aspect with the consideration of the respective players and business models is addressed by the view of "Digital Business Ecosystems". Apple's approach for running the iPod, iPhone and iPad business is a prominent example for this approach [10]. From IT management point of view, such digital business ecosystems are based on information supply chains. The term

“Information Supply Chain” [11,16] describes, how information is produced, processed and used by a certain business process, a company, an organization or within a digital business ecosystem. Therefore, the information supply chain is what IT project management has to plan, manage and control in an M2M- or IoT-Project.

2. M2M ecosystems

M2M ecosystems are based on common building blocks, are using certain platforms and interfaces and communicate via certain protocols. Nevertheless, an M2M ecosystem is designed for a specific application (e.g. energy micro grids). Tailoring is therefore necessary to combine the right components and to adapt them to the specific needs.

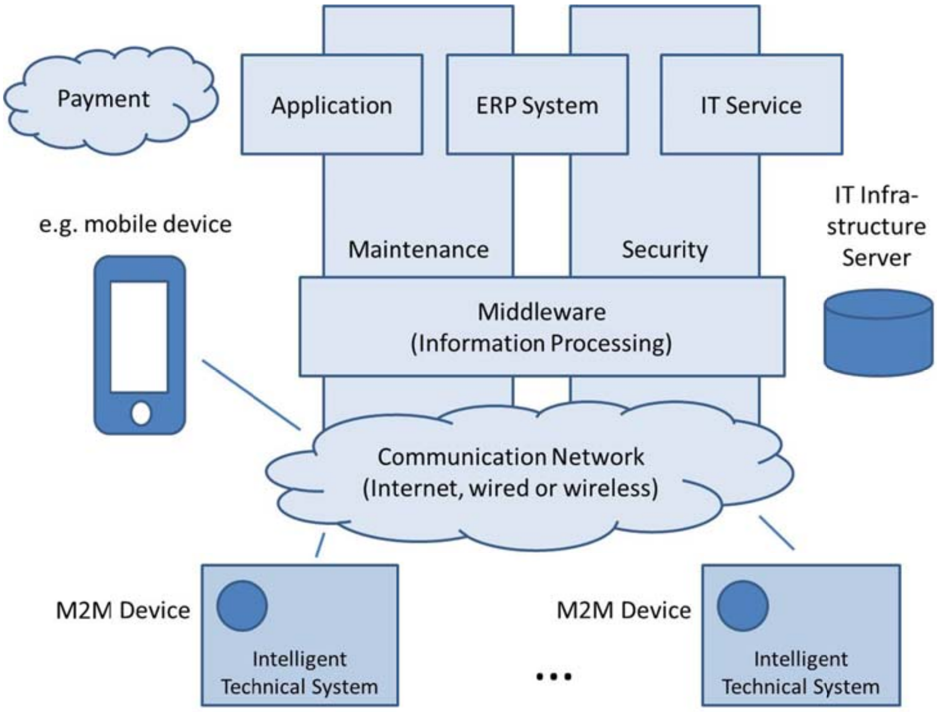

Fig. 2: IT System View of an IoT/M2M System

The typical taxonomy of an M2M system defines certain components:

- The M2M device is a computing device attached to a technical “thing”, e.g. a machine or a sensor. It can collect data, but it can also influence or control the technical system via actuators.
- The M2M gateway is a communication device which connects the M2M device to the communication network. This is usually an internet based network. It can be a wireline or a wireless network (e.g. the UMTS network). Sometimes, the M2M gateway is considered to be part of the M2M device, e.g. there are semiconductor chips integrating both functions.
- The M2M network connects the devices, usually via the Internet Protocol, forming the Internet of Things (IoT). It is part of the M2M network domain.
- The M2M application layer offers IT services for data processing, e.g. deciding to call the maintenance service, if a M2M devices fails. This layer is considered to be a partly

integrated into the M2M middleware. An IT middleware is a collection of services that is forming the interface between the user (or the user application) and the technical system. Since it is processing the data (not only translating) it can be more or less complex.

- Mobile devices or other internet based devices can be considered to be part of the M2M system. They are used as interfaces to the M2M system and therefore they are part of the overall ecosystem.
- The M2M application layer is an abstraction of the IT systems dealing with the processing and control of the M2M data. Using the ecosystem view, the application layer is much more complex. Applications are basically all systems using the underlying M2M system. This can be the integration into ERP systems (e.g. for managing supply chains), into PLM systems (e.g. controlling production systems) or the connection to business intelligence and data mining tools. In this case, the M2M system is just the connection of the IT systems from the virtual domain (cyber space) with the "things" in the real world. The intelligent combination of IT systems like ERP or business intelligence with M2M systems is the core of the digital business ecosystem.
- Another part of the digital business ecosystem is the operation and maintenance of the underlying IT infrastructure (e.g. server systems, backup systems, firewalls, communication networks).
- Payment services are required to create a business model for the digital business ecosystem.
- Security is a very important part. Since the Internet of Things is connected with the world wide internet, all security issues from this domain are entering the world of things. A solid security concept is part of all digital business ecosystems.
- The development of valid business models is part of a digital business ecosystem, too. To create economic value is a major challenge in today's internet businesses. For M2M ecosystems, this question is not really solved yet. The creation of a business model for a specific application case requires as much tailoring and adaptations as for the technical system.
- Last but not least, technical systems like M2M systems have to be used by human beings. At some point, the question comes up where the human being fits in. In many cases, this is not just the user but a number of stakeholders (e.g. in renewable energy systems). Participation of users and stakeholders already during the development but definitively during the operation of a digital business ecosystem is crucial for the success.

Connecting the components and stakeholders, defining the (business processes) amongst them and deriving the information flows between them (the respective information supply chain) is a systems engineering task. It requires a M2M systems engineering methodology and respective processes and tools.

Therefore, one type of IT projects in the context of M2M ecosystems is the design (or engineering) of such M2M systems. It seems to be straightforward to take the learning from software development projects (e.g. software engineering methodology) into account and to run such IT projects in a similar way. Furthermore, a lot of experience from systems engineering projects exist [18,19].

The second type of related IT projects in the context of M2M ecosystems is about the adaptation, installation, roll-out and operation of such a system. It is more similar to "classical" IT projects with aspects of business process reengineering [20]. With this kind of projects, people from business administration and business computing feel much more comfortable. The huge body of knowledge on IT project management deals mainly with such projects.

One of the most prominent use cases for a digital business ecosystem based on M2M communication are energy micro grids. Such micro grids (or smart grids) are expected to be the technical back bone of de-central renewable energy systems. Using a de-central micro grid has several advantages over traditional national grids. It is expected to form a more stable overall energy system since complexity is reduced and a failing micro grid does not necessarily harm other micro grids. The value chain remains local instead of draining money out of the region. The involvement of many players both as consumer and producers (a so-called prosumer [21]) is an instrument for stakeholder participation and for changing the socio-economic environment. Renewable energy is generated in smaller facilities and require de-central approaches.

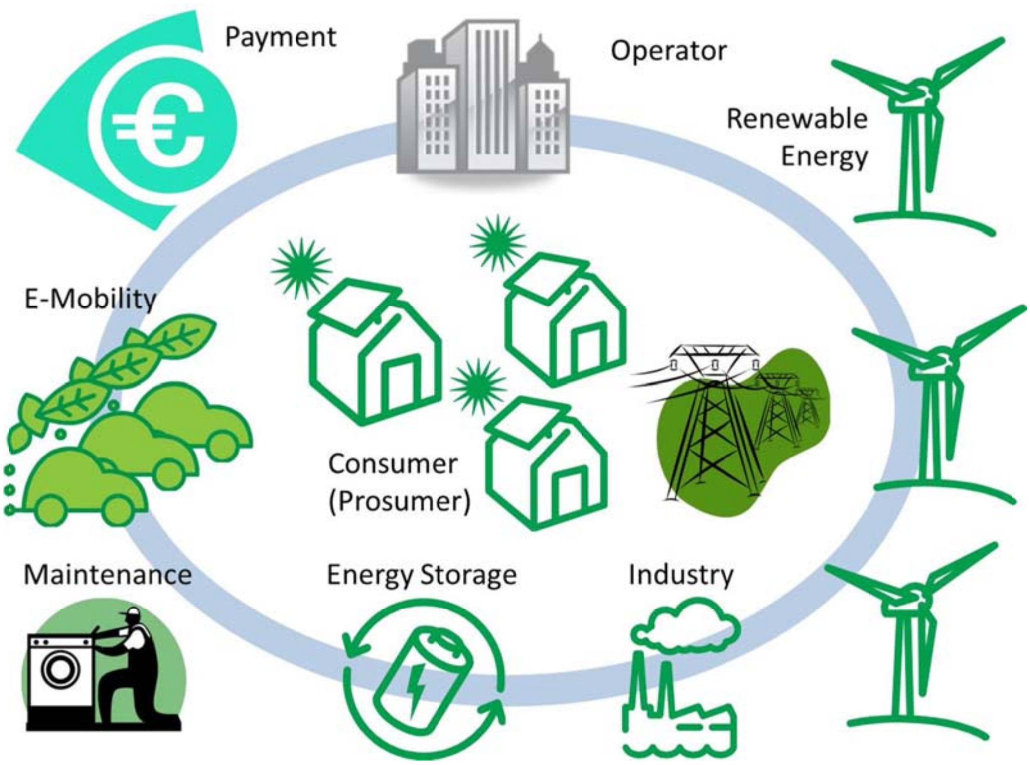

Fig 3: Example of an IoT/M2M Ecosystem: Micro Grid Setup for De-central Energy Systems

For a digital business ecosystem a micro grid forms a typical application case. The production and consumption of the energy has to be balanced permanently. This requires constant communication between producers and consumers and control of a big number of de-central technical systems. Mobile systems like e-cars can be used to store energy or to consume energy. Users in households want to optimize their energy usage. Maintenance needs to be organized, ideally as predictive maintenance (fixing a part before it fails). All these tasks can be managed by using IT services and a M2M system. To create a business case, both the energy and the services need to be charged to the user. Payment services are an IT service, too.

Apart from technical control, more sophisticated services can emerge, e.g. several operators of wind mills combine their purchase power to get better prices for maintenance services. The maintenance service provider on the other hand can optimize the service tour of his staff by using M2M data. In such a digital ecosystem, the computing power and communication capability helps to create an added value.

3. Information Supply Chain

From information processing point of view, the flow of information through the layers of the M2M systems forms an information supply chain [11,16]. Similar to a logistics supply chain, the information supply chain has to make information available to the right users at the right time and at the right place. Managing information supply chains (ISCs) is pretty similar to supply chain management (SCM) for logistics. Therefore, many concepts (e.g. process modeling) are state of the art. Nevertheless, an information supply chain (ISC) is an IT system and it is intended to work fully automized with very limited human interaction (only maintenance and end user layer). The challenge is to integrate various IT systems, services and applications (probably from various IT suppliers). Interfaces and interaction amongst the components have to be defined. The hardware platforms need to be able to support the IT systems. The overall system has to be reliable and offer the required performance. Further big IT topics like IT security, payment services, IT maintenance and control need to be addressed when designing the information supply chain (ISC) for a specific use case.

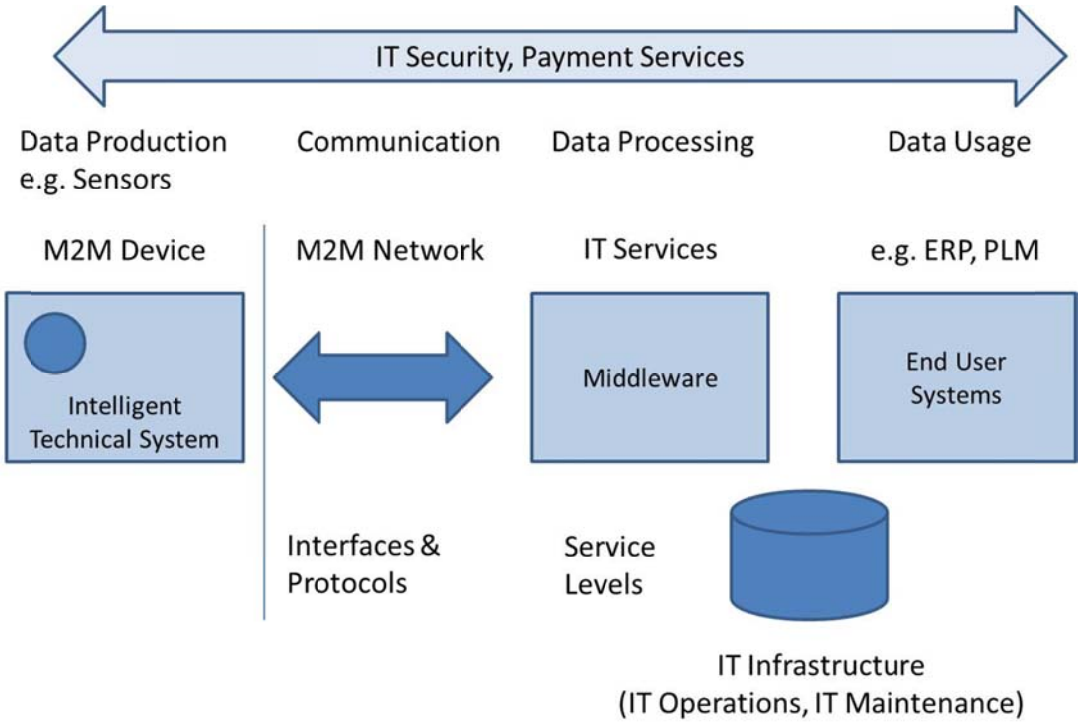

Fig. 4: Information Supply Chain of an IoT/M2M System

Information supply chains deal with the capture and delivery of information (data). For M2M systems, information is captured by sensors. In addition, it can be delivered to actuators. Both are part of the M2M device, meaning the starting point and the end point of the information supply chain can be the same for some information.

Communication within an M2M information supply chain is an important topic, too. M2M systems are usually distributed over various locations (e.g. factory facilities, a renewable energy region, a house). Communication has to use complex networks, e.g. a mobile phone operator network. In case of an Internet-of-Things (IoT) System, the internet protocol is used with all the underlying complexity and issues (e.g. security) of the internet.

Information processing in M2M systems is done by using middleware systems. Middleware is controlling both the maintenance (e.g. adding or removing M2M devices) and operation (gathering data, reacting to data) of the system. For middleware software, standard platforms and protocols are used. There are ongoing research and development activities targeting a standardized set of platforms and protocols for the Internet-of-Things (IoT) in general and M2M in particular [8]. Nevertheless, for an application specific M2M system, the platforms and protocols have to be tailored to the use case and adapted. Tailoring is important in both M2M systems engineering projects and M2M IT projects.

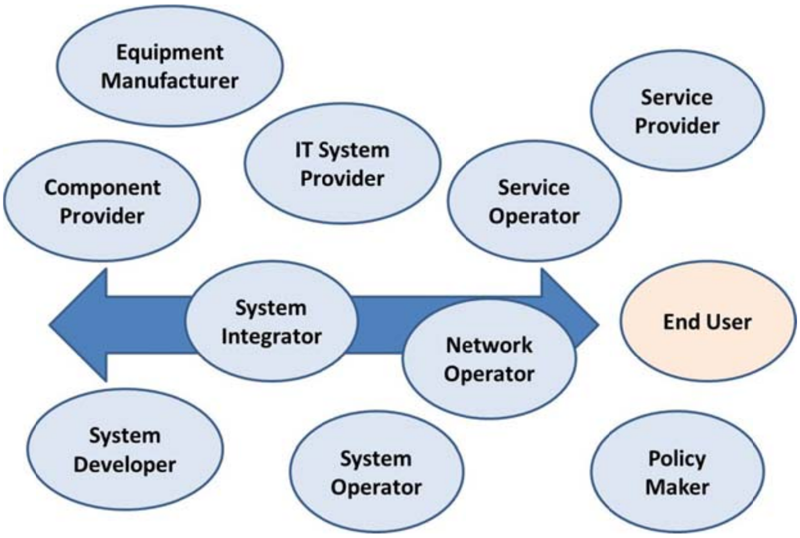

Fig. 5: Players/Value Chain of an IoT/M2M System

Based on the M2M middleware, the end user applications are operated. In many cases, these applications are enterprise resource planning (ERP) tools or business intelligence applications. They are applications from the domain of classical business IT. Both the middleware and the end user applications are operated on PC or server systems. Apart from interfacing with M2M devices, they serve PC applications, web applications and applications on mobile devices (e.g. smart phones, tablets).

Designing an operating an M2M information supply chain (ISC) is driven by the typical two main criteria of IT management:

- The information supply chain has to be designed, tailored and adapted in a way that supports the end user intended benefit. It has to achieve the defined results. Meaning, it has to be **effective**.

- The information supply chain has to achieve the intended benefit by using as few resources (e.g. time, money, energy) as possible. Meaning, it has to do the job **efficiently**.

Furthermore, the operation has to fulfill the expectations towards effectivity and efficiency designed into the information supply chain. Both targets have to be considered when shaping the M2M information supply chain to its needs.

Apart from finding a proper technical solution for the information supply chain, this has to involve an analysis and optimization of the respective value chain. Along the information

supply chain, various players (see Fig. 5) are doing business, creating added value for the end customer and charge money. Since M2M information supply chains are not a standard product but a tailored and adapted application specific product (or at least an application specific standard product – ASSP) there is no player providing complete off-the-shelf systems. Usually, there are companies covering only one (or at least only a few) roles in the value chain. Nevertheless, the business cases have to work for each player. Designing an optimized business process along the value chain is still a major topic for M2M systems.

4. Major Challenges and Problem Characteristics

The definition of a IT project management methodology for M2M projects needs to be based on the main characteristics of the respective project domain.

First, it has to consider two pretty different types of projects:

a) M2M systems engineering projects which develop the technical system according to the needs of the use case. This is comparable to software engineering projects.
b) IT projects which tailor, adapt, roll-out and operate M2M systems. This is comparable to classical IT project management.

Second, three major streams of a M2M project need to be managed in parallel and – even more important – have to be synchronized and connected:

a) The technical project which is designing, tailoring and operating the respective information supply chain.
b) The business project which is creating and running the value chain for the use case.
c) A change project which is considering impact on the socio-economic environment and dealing with the internal and external stakeholders.

Understanding this classification into different views on the same project (usually, a M2M project will contain all aspects) the main characteristics differentiating M2M projects from other IT projects can be described:

- M2M/IoT systems and the respective digital business ecosystems are inherently **de-central**. Due to the complexity (number of devices, number of players, diversity of devices/players, inherent dynamics) a central or hierarchical approach to handle them is likely to fail. The systems and accordingly the projects have to be based on a process oriented organization paradigm or (better) on a networked (peer-to-peer) approach. Hierarchy based organizations are likely to create digital business ecosystems lacking the flexibility to re-act to changes.

- Setting up the required information supply chains and value chains results in a **vertical integration** of components, services, business models and players. This leads to a **cross-domain** collaboration. The issue of a common language versus domain specific languages arises for both the technical and human players. This area has to be understood and to be addressed by project management. Otherwise, the complexity is not manageable.

- The high number of stakeholders and the impact of digital business ecosystems on the socio-economic environment (in addition to the technical environment) carry specific challenges for project management. The change management character of the project needs to be addressed. This requires **stakeholder participation**. For the acceptance of

the M2M system it is crucial to think about stakeholder participation. Elderly people will have issue to accept a smart home deciding about their daily life. A renewable energy micro grid will not be accepted by people if it only for the benefit of a multi-national energy provider. A solution for stakeholder participation in M2M/IoT systems can be the integration with the social web approaches. An example can be the setup of a "thingbook" where profiles of things can interact with both the human user and the machine. People can influence the M2M/IoT system e.g. by forming groups or by connecting things according to their "likes".

- **Tailoring** of standardized solutions and protocols to the application specific needs is a promising approach for M2M/IoT systems. Tailoring means both: cutting out unnecessary parts to reduce complexity and adapt per-defined parts to fit to the use case. But apart from tailoring the technical solution (the information supply chain) tailoring needs to be considered for the value chain and for the project management methodology, too. To run all M2M/IoT projects with one project management methodology will make them heavy. To allow the flexibility and speed required in this IT domain, lean project management is mandatory. Meaning, processes and methods need to be tailored to the individual project.

- The value chain for M2M/IoT systems contains various challenges. One major issue is that the main **business model** for internet business does not really work for M2M. Most internet businesses are to some extend based on advertising. Machines don't re-act to advertising. Therefore, it may be difficult to design a digital business ecosystem in the M2M area based on the well know internet business models. Since end-user customers are trained to not paying for IT services in the internet, new ways for creating a value chain need to be defined.

- One main risk and obstacle for digital business ecosystems connected to the internet are **security** issues. Especially for M2M this is not yet solved. Machines were designed with respect to safety in the past. Security was never an issue since the machine was installed in closed workshops and was only open to expert users. Access and control via the internet are new. The stuxnet attack showed which threads are involved with attaching the things to the internet.

These bullet points are not intended to be complete but to serve as a starting point for thing about how an IT project management approach for M2M/IoT systems may look like.

5. Research Questions and Conclusion

The considerations explained in this contribution lead to research questions for future research on project management methodology and information supply chain management for M2M/IoT systems. This contributes to the main research question: How to set up and how to manage a digital business ecosystem in the era of the Internet of Things? Project management research can contribute to solutions for this question by answering specific research questions in this context:

1) What type of IT projects do we deal with in the era of the Internet of Things? What is a proper taxonomy? What is different/similar to known IT projects?

2) What can IT project management re-use from known information supply chain management methodology? Does the information supply chain approach fit for M2M/IoT systems?

3) What does the abstraction as a digital business ecosystem mean for IT projects in the M2M/IoT domain? Does this help to integrate the technical view, the business view and the change management view on such projects?

4) What are the stakeholders in such projects? How do they contribute to the value chain? What are their motivations and interests in such projects? Are there valid business models for the major players within the value chain?

5) Can systems engineering methodology or software engineering methodology be used to design and develop tailored M2M/IoT systems? How much domain specific knowledge is required to run such IT projects?

6) How can effectivity and efficiency be controlled and optimized in M2M/IoT systems? What are valid key performance indicators (KPIs)? What are the dependencies amongst them? How can the M2M information supply chain be tailored and shaped based on these KPIs?

The list of questions is not complete nor validated. Each question can be a research topic on its own but the questions are/may be dependent on each other. The conclusion from this contribution may be to start to find out about this.

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